THE EFFECT OF COLOR ON VISUAL VELOCITY ESTIMATION

by

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THESIS

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ABSTRACT

This study reports an investigation of the effects caused by the color of a moving light source on the ability of subjects to estimate the velocity of that light source. The variable used for comparison was travel time estimated over fixed distances. The study also provides an investigation into possible differences in the travel time estimate between an experienced and an inexperienced group of subjects. The experiment varied the color of the light source, the distance over which the estimation was made, and the velocity of the light source presented to the subjects. Results showed that the color had no significant effect on the ability of the subjects to estimate travel time and, therefore, velocity. The results also showed that no significant difference existed between the groups of subjects tested.

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PREFACE

Does the color of a vehicle have any bearing on the number of speeding citations received? There are many people convinced that Highway Patrol Officers would be more likely to track a bright colored eye catching vehicle than another simply because it appears to be traveling faster. It has been assumed by a large group of individuals that the impression of high speed is inherent within certain colors. I admit to membership in this group. As a pilot, I have also wondered if the color of an aircraft might not affect the velocity estimation of enemy gunners either on the ground or in the air during a war time situation. If it does, it is entirely possible that combat losses could be reduced by using certain colors when painting aircraft.

Armed with this strong basic interest and a feeling that some significant military application could result, I set out to determine the effect colors have on velocity estimation.

I am extremely grateful to Mr. R. Smith and Mr. J. Bly of the Applied Physics Laboratory for their advice, time, and physical effort in designing of and building the device so important to this experiment. I cannot say enough to express my gratitude to Lieutenant Sked and his men of the California Highway Patrol Station in Salinas, California. Their cooperation and enthusiasm as subjects for this study was without bound and extremely encouraging. Without the help of these individuals, I could not have even begun this basic experiment.

I would also like to offer very heartfelt thanks to my thesis advisor, Dr. G. K. Poock, for his continuous encouragement and help.

Without his help, I would not have been able to start this research much less complete it.

I. INTRODUCTION

Although, in an off hand manner, quite a few people very seriously wonder what possible effects color has on velocity estimation, it is difficult if not impossible to find any reference to actual experimental work done to make known any possible relationships. A great deal of experimental research has been documented in both visual velocity estimation and the visual effects of color, but the author could find no documentation of work done on the interactions of the two. Therefore, it is the purpose of this paper to provide an initial study on the effects of color on visual velocity estimation. Within this process, it is a secondary objective of this paper to determine whether a more experienced group of individuals, California Highway Patrol Officers, are affected to some degree unlike a less experienced group, Officers from the Naval Postgraduate School.

Therefore, the experiment as reported here will test the hypothesis that, using three velocities and three distances, four different colors will not cause unlike effects on visual estimation of the travel time of a moving light source. It is further hypothesized that the group of California Highway Patrol Officers will not differ from the group of Officers from the Naval Postgraduate School in travel time estimation.

II. METHOD

A. APPARATUS

The equipment constructed to provide control to the entire experiment consists of a single box, thirty inches in length, six inches wide, and four inches in depth, as shown in Figure 1. On the face of this box are four slots one fourth of an inch wide running nine inches along the length of the box. These slots are placed one inch apart starting three inches from the left edge and one inch from the top and bottom of the face of the box. These are referred to as the horizontal or track slots. Nine inches to the right of the terminating end of the horizontal slots are the first of three vertical slots, oriented ninety degrees from the horizontal slots. The vertical slots are four inches in length, one fourth of an inch wide and three inches from one to the next. These are referred to as vertical or target slots.

Fastened to the underside of each of the track slots is one of the four colored plastic sheets used to create the illusion that a moving light source has a given color. A blue sheet of plastic is fastened to the top or first slot, amber to the second, green to the third, and red to the fourth and last slot. A graphical representation of wavelength versus percentage of light transmission for each of the four colored plastic sheets is shown in Figure 2. This graph was created on a Baush and Lomb Spectronic 505 Spectrophotometer using the four colored plastic sheets. It gives a rather good representation of the filtering quality and broad wavelength spectrum of the materials used.

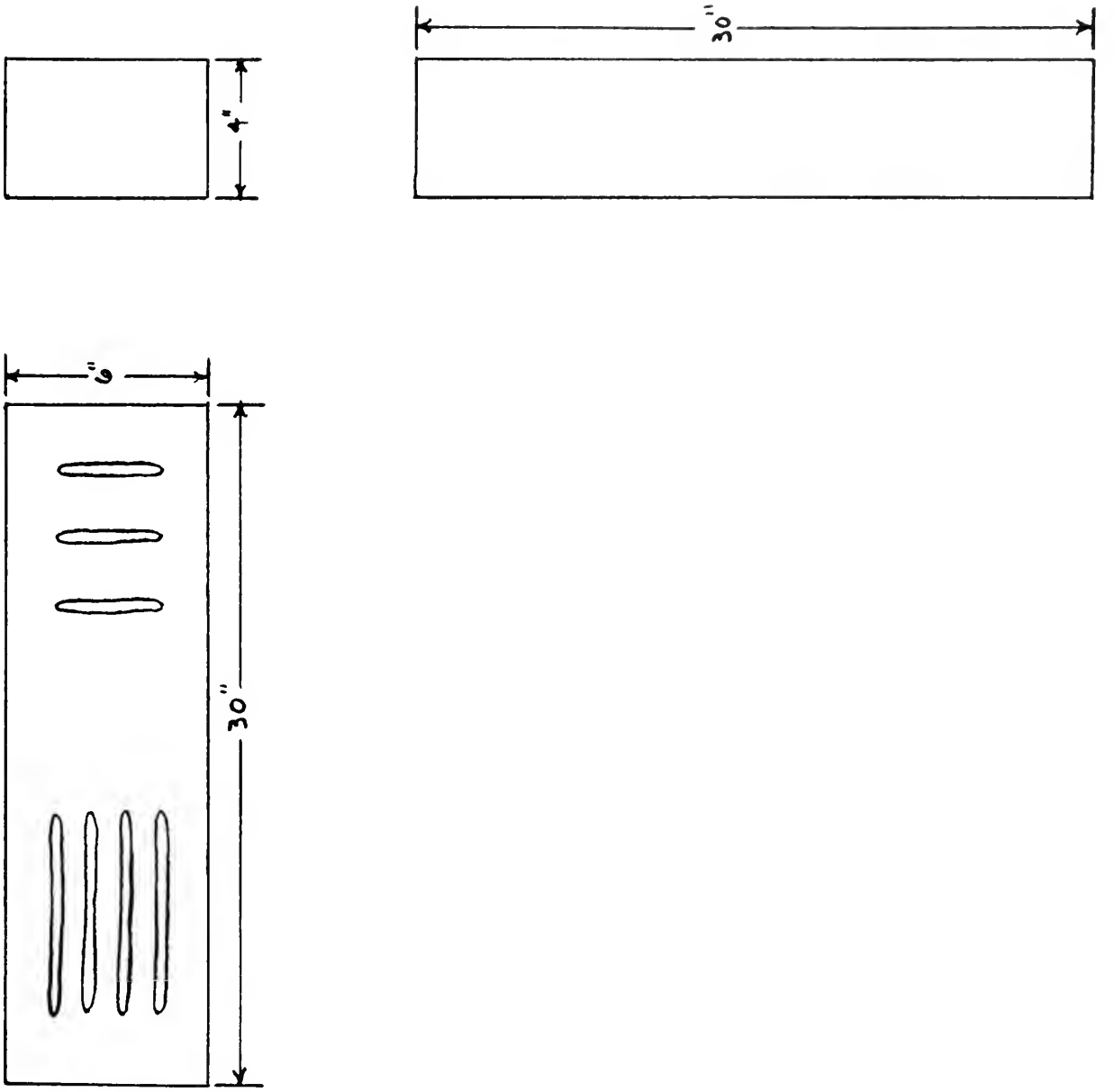
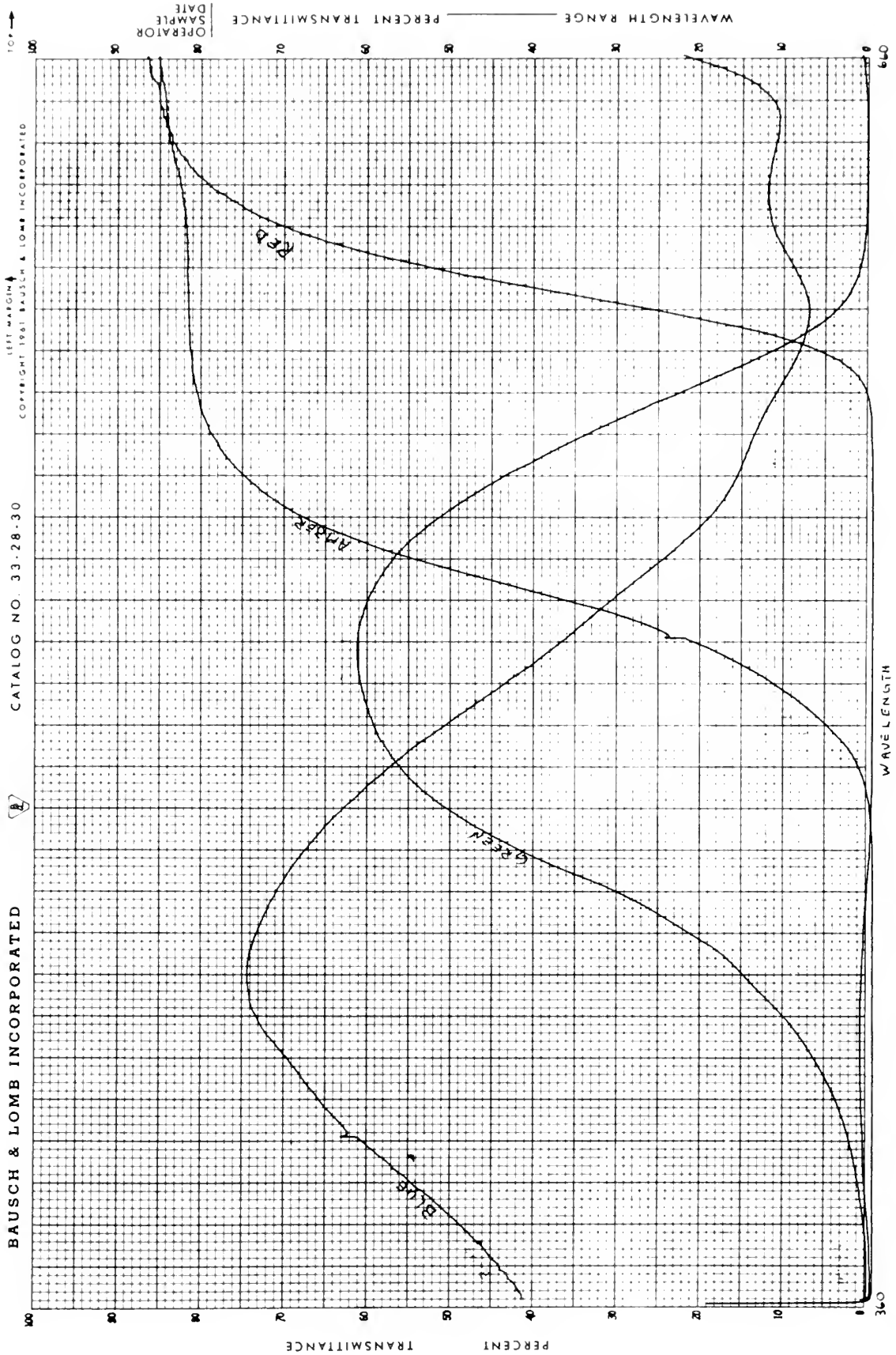


Figure 1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LEFT MARGIN
WAVELENGTH
PERCENT TRANSMITTANCE
WAVELENGTH RANGE
PERCENT TRANSMITTANCE
OPERATOR
SAMPLE
DATE
RED
AMBER
GREEN
BLUE
340
640

Figure 2

Each of the target slots can be lighted from within, singly or in groups. To prevent glare from the light sources, sheets of onion skin paper are fastened to the underside of these slots, diffusing the light.

To provide the moving light source, an endless four and one half inch wide belt is mounted on two one and one half inch ridged drums, to prevent the belt from leaving a constant track. Four holes are punched in the belt, positioned so that each is centered under one of the track slots. They are punched in a line parallel to the target slots so that all four appear to be traveling together when the target slots are all uncovered. The drums are fastened to a metal base and allowed to rotate freely just above it. Also fastened to this base are a series of light bulbs placed within the area about which the belt turns. These lights are placed at an offset from the punched holes to reduce the possiblity of glare but at the same time provide a light source over the entire length of the track slots. A variable speed motor dependent upon voltage applied is geared to rotate one of the drums and thus the belt mounted on it. A small variable voltage generator capable of providing from zero to thirty volts provides the impetus to this motor.

An electronic pointer timer gauged in hundredths of a second provides a measure of the travel time estimation. The timer is triggered by voltage sent to it from a circuit closed by a relay, with the initiation of this process provided by a photo electric cell. This photo electric cell is fastened to the terminating edge of the third track slot and oriented directly at the corresponding punched hole in the belt. The timer is stopped by a push button mechanism which reopens the circuit via the same relay used by the photo electric cell to close the circuit.

Four pieces of black plastic opaque tape are used to cover the track slots and are removed and replaced individually to expose a single colored light source at a time.

B. TEST SITE AND SUBJECTS

Each of the two groups of subjects were tested under conditions forced by the availability of the subjects and the reluctance of the author to request that the Highway Patrol Officers give up some of their off duty time for the experiment. As a result, each of the ten subjects from the Highway Patrol were tested in the confines of the well lighted briefing room of the station during normal duty hours. The subjects were picked at random as they had free time from their office and patrol duties. Each of the subjects tested had at least two years of experience with the Highway Patrol. This and the need that each subject not be color blind, a Highway Patrol requirement, were the only criteria for selection.

The ten Officers from the Naval Postgraduate School were volunteers picked as randomly as possible. These subjects were also tested during normal duty hours, but each could be tested in the Human Factors Laboratory due to its close proximity to classes. This laboratory was somewhat less well lighted than the briefing room at the Highway Patrol Station and had fewer potential interruptions. The only criterion placed upon these subjects was that they too could not be color blind. As a cross check of this point, each was asked to identify the four colors used in the experiment. In fact, all twenty of the subjects were asked to do this. None of the twenty subjects were color blind.

C. EXPERIMENTAL DESIGN

The experiment was carried out as a nested factorial design. The two factors of experimental interest were the effect of the four colors on the estimated travel time and whether a difference existed in the estimated travel time between the two groups of subjects. There were two control variables used in the experiment and the first, velocity of the colored light source, was varied three ways: 1.30, 3.21, and 5.33 inches per second. The second variable, distance over which the travel time was estimated, was also varied three ways: nine, twelve, and fifteen inches. The twenty subjects ran through the thirty six experimental conditions two times each for a total of 1440 observations.

During the experiment, no attempt was made to eliminate noise or interruptions provided by the surrounding environment or from the equipment itself, except to delete an observation in the middle of which some major interruption occurred. In fact, the changes in pitch of the motor driving the light source corresponding to the velocity served as an alerting factor for the subject. This was thought to be desirable since it made it almost impossible for the subject to miss the initiation of a new observation and be forced into making errors. The subjects were each seated in an upright position at a relatively constant distance, six feet, from the experimental equipment. They were not allowed to have a view of the timer or the voltage generator. The equipment itself was oriented so that the full scope of the device was presented to the subject for easy visual reference. The order of the combination of color, velocity, and distance presented to the subject was semi-random.

D. INSTRUCTIONS AND PRACTICE

The subjects were instructed to follow the colored light source along the uncovered track slot in any way they wished and that it was their task to estimate the length of time it would take the light source to reach the single lighted target slot if it were to continue traveling at the same rate beyond the point where it disappeared at the end of the track slot. They were told to indicate the proposed arrival of the light source at the target by pressing the "pickle" button to stop the timer. They were also told that the noise of the drive motor would cease shortly after the light source disappeared from view and that they should ignore this situation as much as possible since it had no bearing on the experiment.

Each subject was allowed two practice trials to orient himself to the conditions of the experiment. Both of the practice trials were run using the blue colored light source traveling at 4.27 inches per second, a velocity not used in the experiment itself, with the target set at a distance of twelve inches from the terminating end of the track slots.

As each color appeared for the first time, the subject was asked to identify that color just to see if he might be blind to it.

III. RESULTS

The analysis of variance, Table 1, shows that neither of the two factors of experimental interest, the effect of color on estimated travel time or the difference in estimated travel time between the two groups of subjects, were significant.

There is, however, a great deal of significance indicated for the control variables of velocity and distance. This is a rather obvious result since the levels of both were varied a significant amount so that the travel times could vary over a wide range of estimated values. It also seems obvious that there should be a distinct difference between the individual subjects as indicated by the significance of Subjects Within Groups. The six significant interactions can all be related directly to the obvious differences in velocity, distance and individuals as mentioned above. Therefore, they reflect no significance stemming from the factors of experimental interest.

Table 1

Analysis of Variance

Source	df	MS	F
Group Type (G)	1	59.24	0.54(NS)
Subjects Within Groups (SWG)	18	108.96	110.06
Color (C)	3	2.06	1.89(NS)
Speed (Sp)	2	4357.59	263.78
Distance (D)	2	978.80	192.68
G x C	3	0.66	0.61(NS)
SWG x C	54	1.09	1.10(NS)
G x Sp	2	16.37	0.99(NS)
SWG x Sp	36	16.52	16.69
G x D	2	2.24	0.44(NS)
SWG x D	36	5.08	5.13
C x Sp	6	0.64	0.99(NS)
C x D	6	0.45	0.76(NS)
Sp x D	4	72.34	55.22
G x C x Sp	6	0.55	0.85(NS)
SWG x C x Sp	108	0.65	0.66(NS)
G x C x D	6	0.42	0.71(NS)
SWG x C x D	108	0.59	0.60(NS)
C x Sp x D	12	1.73	2.16
G x D x Sp	4	3.95	3.02
SWG x D x Sp	72	1.31	1.32
G x D x C x Sp	12	0.82	1.03(NS)
SWG x D x C x Sp	216	0.80	0.81(NS)
ERROR	720	0.99	
Total	1439		

(NS) = not significant P > .05

IV. DISCUSSION

The experiment reported here definitely indicates that the color of a moving light source has no effect on the estimation of travel time or velocity by an individual. It also indicates that the California Highway Patrol Officers did not differ from Officers at the Naval Postgraduate School when estimating the travel time or velocity of a moving colored light source. This would seem to indicate that experience is not important in velocity estimation. These results can be explained very simply by stating that just as indicated, color has no effect on an individual estimating the velocity of a moving object and that experience indeed has no effect on these same estimates. However, it is also possible that this particular experiment is too restricted to provide detection of any possible effects.

The distances over which the travel time was estimated may have been too short and possibly too closely related to the observed track length where the light source traveled. As a possible result, the subject could make a mentally mechanical timing of the observed light source simply by counting. He could then compare this to the distance over which the estimation was to be made and then count down to "pickle" time. This would be nothing more than an educated guess based solely on comparisons, making the color of the light source and experience of the subject irrelevent. A wider separation of the target slots both from each other and, more importantly, from the terminating end of the track slots, possibly by separating them bodily within the equipment design, could eliminate this mechanical comparison and make any possible color effects more likely to show significance, if there is any.

Another area in which influence may have been exerted on the results is the colors themselves. It is possible that the high level of light transmission through the colored plastic material used in the experiment, Figure 2, had a tendency to overcome differences in color. This is to say that each moving light source may have appeared simply as a bright light which was essentially white to the subject. None of the subjects was color blind and each correctly identified the colors involved in the experiment, but under the pressure of estimating the travel time of each light source, maybe each color became nothing more than just a light. The intensity of the light source under these conditions may have been too high to allow their colors to influence the subjects.

Since the light source had no mass, it is possible that errors in visual judgement were created. This could account for the lack of influence that the experience of the Highway Patrol Officers had when compared to that of the Officers of the Naval Postgraduate School. The Highway Patrol Officers' experience is based on velocity estimation of vehicles of relatively large mass. In addition, a moving object of some mass would have provided more color, by cross sectional area alone, so that visual judgement might show more effects than indicated here.

Due to a number of circumstances, the environment within which the experiment was conducted was not at all well controlled or very consistent. The laboratory environment in which the Naval Postgraduate School Officers were tested was relatively free from outside influences and interruptions. It was consistent and conditions were fairly well controlled. However, due to the author's reluctance to

request that the Highway Patrol Officers come to the laboratory during off duty hours, these subjects were tested in an experimentally uncontrolled environment, the briefing room at the Highway Patrol Station. The normal operations alone created a number of interruptions and outside noises which could not be prevented without shutting down Highway Patrol operations for the duration of the experiment. It is quite likely that some significant influence was forced upon these subjects by the environment. It must be said, however, that the forces of concentration of each of the Highway Patrol Officers tested was well above what the author considers average.

The results of this experiment are based solely upon estimated travel time and not upon differences from real world or true conditions of the experiment. It is quite possible that each of the subjects involved in this research was making an estimation error of the same type as each of the other subjects. The actual time that a light source would have taken to reach the target may have been consistently greater or less than the estimated travel times indicated by each of the subjects. On the other hand, the estimates may have bracketed the actual times. However, these possibilities were not considered within the scope of this study, but they may have caused some deviation from quite different results than found here. A look into these possible error trends could prove very beneficial.

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13. ABSTRACT

This study reports an investigation of the effects caused by the color of a moving light source on the ability of subjects to estimate the velocity of that light source. The variable used for comparison was travel time estimated over fixed distances. The study also provides an investigation into possible differences in the travel time estimate between an experienced and an inexperienced group of subjects. The experiment varied the color of the light source, the distance over which the estimation was made, and the velocity of the light source presented to the subjects. Results showed that the color had no significant effect on the ability of the subjects to estimate travel time and, therefore, velocity. The results also showed that no significant difference existed between the groups of subjects tested.

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moving light source						
experienced subject						
color effects						
varied colors						
estimates over fixed distances						
varied velocities						
inexperienced subjects						